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PHYSICAL AND FAUNAL EVOLUTION OF NORTH AMERICA DURING ORDOVICIC, SILURIC, AND EARLY DEVONIC TIME

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IV

The following classification of the Ordovicic[1] and Siluric has recently been published by the author and will be made the basis of the present discussion of these systems:[2]

F. Upper Siluric or *Monroan.*
E. Middle Siluric or *Salinan.*
D. Lower Siluric or *Niagaran.*
C. Upper Ordovicic or *Trentonian.*
B. Middle Ordovicic or *Chazyan.*
A. Lower Ordovicic or *Beekmantownian.*

A. THE LOWER ORDOVICIC OR BEEKMANTOWNIAN

At the beginning of Ordovicic time, as now generally recognized, the great marine transgression or positive diastrophic movement, which obtained throughout Upper Cambric time, was in progress, so that the early Beekmantown strata overlapped the Upper Cambric (Saratogan) and came to rest directly upon the crystalline basement. The basal portion of the sedimentary series is generally quartz sandstone of greater or less purity, or sometimes a conglomerate with crystalline pebbles of local origin. This basal sandstone is commonly referred to the "Potsdam," that term being used synonymously with Upper Cambric. Aside from the question as to whether or not the Potsdam sandstone of the type locality is really of Upper Cambric age, it must of course be apparent that in a normally overlapping series of strata deposited by a transgressing sea, the basal sand member would naturally rise in the series in the direction of transgression and overlap, and that hence a basal sand is not everywhere of the same age. In northwestern New York, in Ontario, and in northern Michigan, these basal sands are probably in all cases

[1] This journal does not approve the terms "Ordovicic," "Siluric," etc.

[2] *Science,* N. S., Vol. XXIX, pp. 351–56, February, 1909.

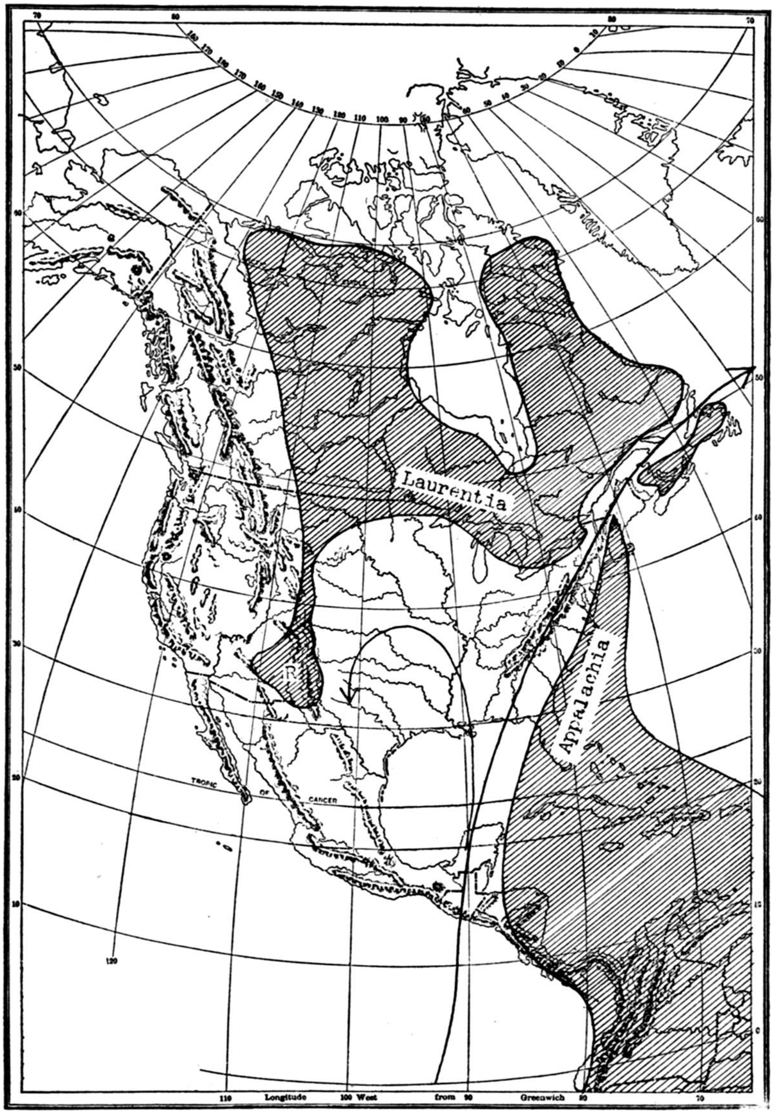

Fig. 1.—Paleogeographic map of North America at end of Upper Cambric time, and probable currents. R. Peninsula of Rockymontana.

post-Saratogan, belonging to the basal portion of the Beekmantown series as generally defined. This is clearly true of the conglomeritic layer at the base of the Little Falls dolomite in the Mohawk Valley, and is probably also true of the so-called Potsdam of the Black River region and the westward continuation of the outcrop in Canada. There is good reason for believing that the sea at the end of Saratogan time did not cover the present site of Lake Ontario, and that the basal sandstones of the Ontario region belong to the base of the overlapping early Beekmantown. In some cases the basal sands (St. Mary's sands) are even younger than this (Lowville, N. Y., Encampment d'Ours, Isle Lacloche, etc.), for the immediately overlying strata carry late Chazy (Lowville) or even Black River fossils, and, so far as now known, there is no break in sedimentation between these basal sands and the beds immediately succeeding, which thus determine their age. In all such cases, until positive evidence of a pronounced physical break or disconformity is determined between the two series, or until the basal bed is shown by unquestionable fossil evidence (exclusive of Scolithus, burrows, trails, and other problematic markings which may characterize various Paleozoic sandstones) to be of Cambric age, logical reasoning compels us to regard the age of the basal sandstone in each case as essentially that of the fossiliferous beds immediately succeeding, unless these are the very lowest post-Cambric beds.

One other point should be clearly emphasized. It is by no means established that the basal sandstones are everywhere of marine origin. In fact, the general absence of fossils, the frequent cross-bedding and other characters point rather to a continental origin of a part, at least, of this basal series, the agents of deposition being rivers or the wind. There is scarcely a geologist today who is satisfied with the complacent explanation, current only a short time ago, that the absence of fossils in a sandstone is due to "unfavorable conditions at the time of deposition," or to subsequent destruction of the fossils, in some mysterious way or other. That fossils abound in marine sandstones of all kinds, and even in conglomerates, is a well-known fact, and that the sands along our modern sea-shores are rich in shells and other hard parts of organisms, is equally a matter of common knowledge. The argument that the absence of fossils in a

rock which elsewhere carries them, indicates some peculiarity of the sea-shore at that point, capable of barring the life of the sea, is a laborious explanation to fit a preconceived notion of the origin of the formation in question. Nor must we forget that the North American continent was above the sea during long periods of pre-Cambric and Cambric time, and that on those vast land areas subaërial deposition as well as erosion must have been in progress. It is therefore to be expected that in many, if not in most, regions the Paleozoic series begins with a formation of continental origin, the upper portion of which was reworked by the transgressing sea, and became incorporated as a basal member of the marine series succeeding. In this manner the contact between the continental and marine series often became an apparently conformable and perfectly gradational one, the hiatus between them being masked. It will of course be impossible in such a case to determine whether a basal bed of continental origin is of pre-Cambric, of Cambric, or of post-Cambric age; all that can be determined is the period at which its upper portion was reworked by the transgressing sea. If the basal bed is of slight thickness it is in such a case best referred to the age of the immediately succeeding marine formation.

The question naturally arises, should the lower portion of the Beekmantown be referred to the Cambric with which it forms a continuous transgressive series, or should it be retained in the Ordovicic with the remainder of the Beekmantown? While in New York the fauna is, so far as known, an Ordovicic one, in other localities beds considered of the same age carry a mixed Cambric and Ordovicic fauna. In this respect these beds and the typical Saratogan, as well as the St. Croix series of Minnesota and Wisconsin, probably correspond to the Tremadocien of Europe, which is classed as Upper Cambric by British geologists, but by German and other continental geologists as basal Ordovicic (Unter Silur). Matthew correlates these beds with the *Asaphellus homfrayi* beds of the St. John section, and so places them above the *Dictyonema flabelliforme* beds, which at present are also included in the base of the Ordovicic by some continental geologists. That such transitional formations are to be expected in any complete depositional series is, of course, obvious, and their precise reference is a matter of secondary importance.

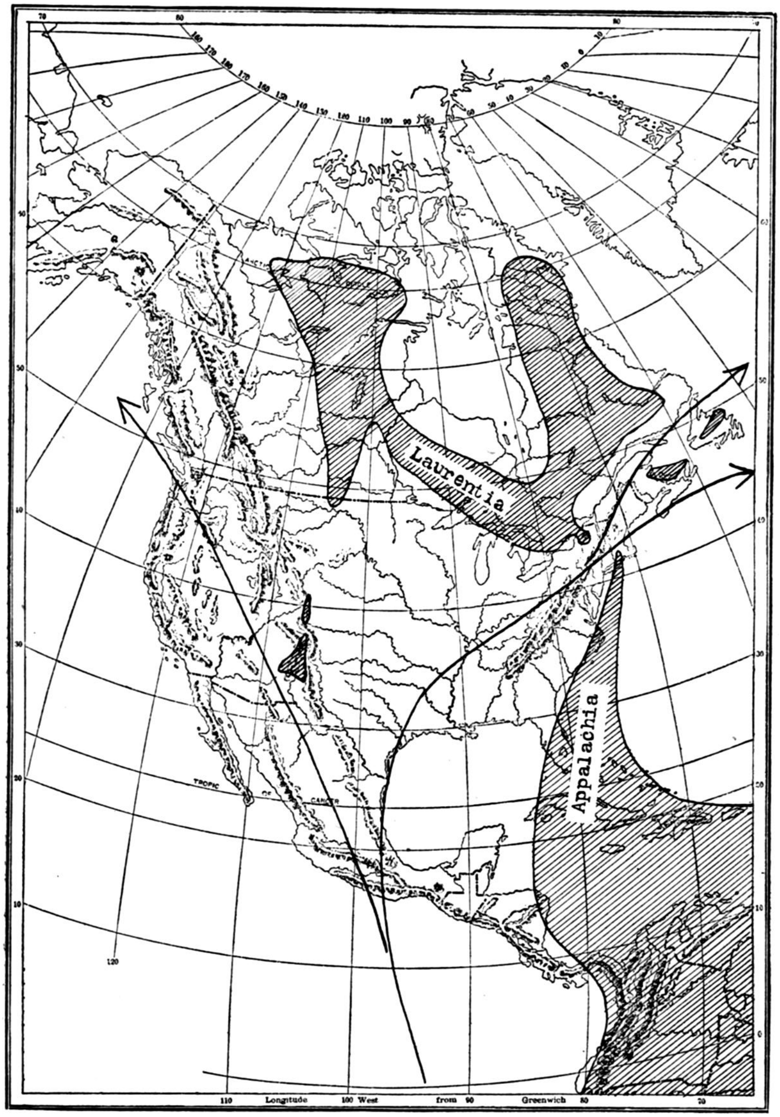

Fig. 2.—Paleogeographic map of North America in early Beekmantownian time, showing extent of maximum transgression and probable currents.

To make a distinct system of them, as has been proposed by some, will not solve the difficulty, because the transitional beds are likely to be of very variable quantitative and chronologic values in different localities. The accepted base of the Ordovicic,—the summit of the Saratoga formation in New York, of the Franconia sandstone in the Mississippi Valley, and of the *Asaphellus homfrayi* beds on the Atlantic coast, is a perfectly satisfactory one, as long as the synchroneity of these formations is granted. (Compare Figs. 1 and 2.)

REGRESSIONAL PHASE OF THE BEEKMANTOWN

As has been fully demonstrated by the author elsewhere[1] and by Berkey,[2] the chief event of Beekmantown time in North America was the widespread regressive movement of the sea and the re-emergence of the continent. The extent of the movement is shown by the extensive disconformity between the Beekmantown and the succeeding Chazy formations. From this it appears that only a narrow trough remained in the Appalachian region as the sole representative of the interior or Mississippian sea, while most of the Pacific coast region, west of the Rocky Mountains axis, was probably uncovered (see map, Fig. 3). In the interior of North America the emergence was accompanied by widespread continental deposition recorded in the St. Peter sandstone. The detailed characteristics of this formation; the all but complete absence of fossils; the cross-bedding shown in many exposures; the rounded character of the sand grains, their grooved and pitted surfaces; the absence of the finer impurities; the uniformity of the size of grain in the same region—all point to long-continued shifting about of these sands by winds, and testify against their marine origin. The inclusions in the quartz grains show them to be derived from the crystalline oldland, the chief source being probably the Canadian shield. In some cases the contact with the underlying formations is abrupt and disconformable, showing that erosion of the uncovered limestones preceded the deposition of the sands. Not infrequently the contact

[1] Grabau, A. W., "Physical Characters and History of Some New York Formations," *Science*, N. S., Vol. XXII., pp. 528 ff., October, 1905; also, "Types of Sedimentary Overlap," *Bull. Geol. Soc. Amer.*, Vol. XVII, pp. 616 ff.

[2] Berkey, C. P., "Paleogeography of St. Peter Time," *Bull. Geol. Soc. Amer.*, Vol. XVII, pp. 229–50.

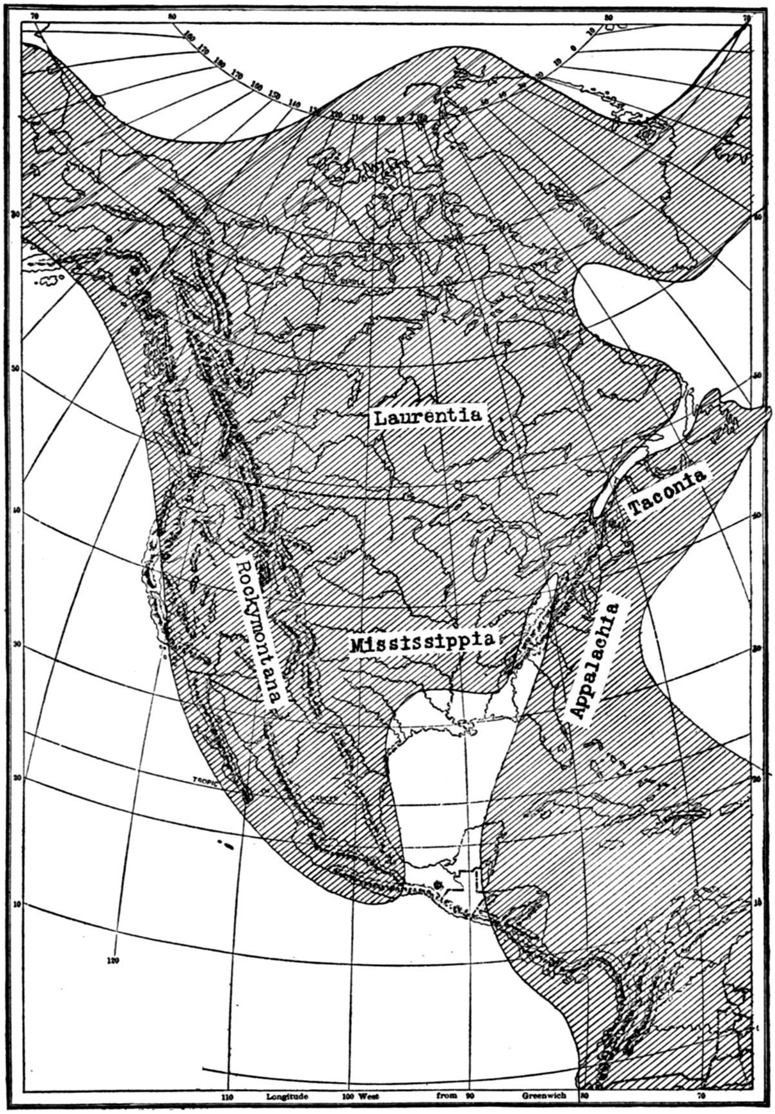

Fig. 3.—Paleogeographic map of North America at the end of Beekmantownian time, showing maximum retreat of the sea.

is as sharply marked as that of aeolian quartz sands found upon the clear-swept limestone floors of some modern deserts.[1] In some cases, however, there appears to be absolute conformity between the St. Peter sandstone and the underlying dolomites, pointing to continuous deposition. Both in Wisconsin and in Minnesota, the lower Magnesian beds are often slightly folded, and the lower St. Peter sandstone is likewise involved in these folds[2] (Fig. 4). The upper St. Peter, however, and the overlying Stones River, which are perfectly conformable, are not involved in these folds. In Minnesota, the Oneota, New Richmond, and Shakopee formations have a combined thickness of 105 to 260 feet. If the Jordan and St. Lawrence beds are regarded as Ordovicic, though they still contain Dicellocephalus, the thickness is increased to 190 feet minimum or 673 feet maximum. The faunas of all the beds of the Lower Magnesian series indicate lowest Ordovicic and close relationship to the Upper Cambric. In the Black River region, Cushing records 20 to 60 feet of lowest Beekmantown (Theresa), succeeded disconformably by Upper Chazy (Pamelia and Lowville limestones). The base is probably not exposed in this section, the basal sandstone, called Potsdam by Cushing, being most likely of later age. In the Mohawk Valley, 350 feet of Beekmantown (Little Falls dolomite) is followed disconformably by Upper Chazy (Lowville); but here, too, the base of the Beekmantown is not shown, and hence the true thickness is unknown. In the Lake Champlain region the Beekmantown is 1,800 feet thick; in southern Pennsylvania 2,250 to 2,300 feet; in central Pennsylvania nearly 2,500 feet; and in the Arbuckle Mountains of Oklahoma 1,250 feet. In all these localities, except central Pennsylvania, the upper limit of the Beekmantown is marked by a dis-

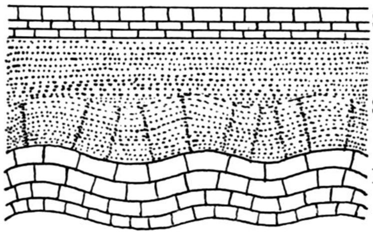

Fig. 4.—Showing the relationship of the Upper Stones River (S. R.) and lower Beekmantown (B.) Beds of Minnesota and the included St. Peter (St. P.) (Redrawn from Hall and Sardeson.)

[1] Compare Zittel, *Beiträge zur Geologie und Palaeontologie der lybischen Wüste.*

[2] Hall and Sardeson, *Bull. Geol. Soc. Amer.*, Vol. III., pp. 354, 355.

conformity, and the highest beds are thus wanting. In Center County, Pennsylvania, the upper beds appear to be completely represented. They are succeeded by 2,335 feet of dolomitic limestones, classed by Collie with the Beekmantown, but for reasons given elsewhere[1] referred by the author to the Chazy; and by 235 feet of limestones of Upper Stones River (Upper Chazy) age. The succession seems to be uninterrupted, placing this section in the region of non-emergence, while the others cited belong in that of emergence during late Beekmantown time. The section in central Pennsylvania does not, however, show the base of the Beekmantown, which is thus thicker than 2,500 feet (see Fig. 5). There seems no reason for doubting that the higher

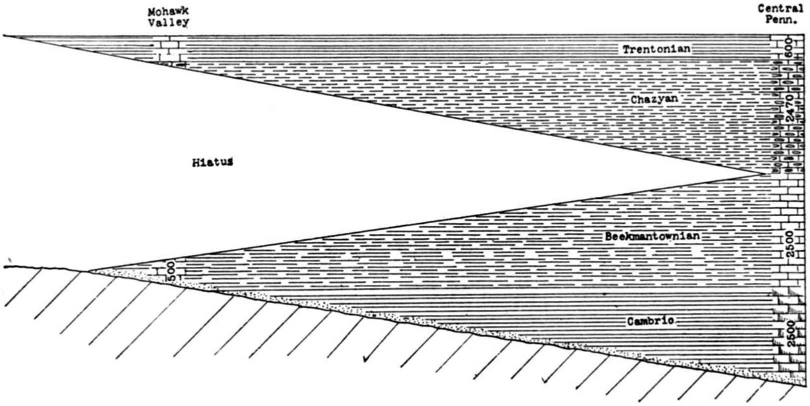

Fig. 5.—Diagram showing relationships between the Mokawk and Central Pennsylvania sections and the character of the overlaps and "off-laps," with the progressively decreasing hiatus.

beds of the Beekmantown were progressively deposited during the slow retreat of the sea, and that each higher member had, in general, a smaller areal distribution than the preceding one. On this view the successive members have the "off-lapping" arrangement of shingles, except that the earlier and lower formations are continuous beneath the higher ones. This is regressive overlap or "off-lap," and seems to supply the only rational explanation answering to the facts. To assume that the whole of the Beekmantown was deposited before retreat began, not only makes the negative diastrophic movement a cataclysmic one, where the positive movement was a very slow

[1] *Types of Sedimentary Overlap*, p. 619.

and regular one, but also necessitates the further assumption of an enormous erosion during the succeeding transgressive movements, which not only removed the greater part of several thousand feet of strata over the northern United States area, but also the whole of the extensive Canadian deposits of Beekmantown which must have reached far toward the Arctic regions, if the entire Beekmantown was deposited as a transgressional series. Aside from the fact that erosion would scarcely be very active during a positive diastrophic movement or transgression of the sea, it can hardly be assumed that such extensive erosion preceded the deposition of the St. Peter sandstone and the Chazy formation. Moreover, the intimate relation between the Lower St. Peter and the underlying Lower Beekmantown demands a close succession in deposition, the lower sand beds being probably deposited by the shoaling sea itself. If that is indeed the case, no higher dolomites of Beekmantown age than are now found ever existed in the Minnesota area.

West of the Rocky Mountains, the basal Uinta quartzite is chiefly if not wholly a continental deposit of pre marine Cambric time, 12,000 feet or more in thickness. Upon this enormous basement series the eastward-transgressing Cambric sea laid down its progressively overlapping strata, the upper beds of the series being reworked during the progress. The transgressing sea apparently did not reach the region of the eastern Uintas, where the basal quartzite is succeeded by the Lodore shales. From these shales Powell reported Carboniferous (Mississippic?) fossils,[1] and he gives evidence of the existence of a disconformity between these shales and the basal sandstone. Weeks[2] identifies the Lodore with the Iron Creek shales of Berkey, which lie between the Uinta and the Ogden quartzites, and which Berkey correctly correlates with the Cambro-Ordovicic Ute limestone of the Wasatch. Weeks fails to recognize that, as Berkey has shown, the Ogden quartzite has united with the Uinta in the eastern section, the intervening shales having wedged out. The Lodore of the eastern Uintas thus lies above the Ogden horizon, and corresponds to a part of the overlapping Mississippic series (see Fig. 6).

The Lower Ordovicic retreat is shown in the western section by the

[1] *Geology of the Uinta Mountains.*

[2] *Bull. Geol. Soc. Amer.*, Vol. XVIII, pp. 435, 436.

appearance of the Ogden quartzite and conglomerate, which bears internal evidence of continental, chiefly river, origin; and to all appearance represents the sand and gravel wash which followed the retreating sea westward, and which was probably in large part derived from the basal Uinta quartzites, with which the Ogden seems to become confluent in the eastern Uintas.[1] This quartzite rests on higher beds in the western sections than in the eastern, thus showing the same relationship to the underlying series that is exhibited by the St. Peter sandstone. In the western Uintas it is underlain by 1,200 feet of shales, regarded as Cambric, though the highest beds may represent the Lower Ordovicic. In the Wasatch Mountains the Ute limestone, 2,000 feet thick, and of Cambro-Ordovicic age, lies between the Ogden and Uinta quartzites. In the Eureka section of central Nevada, the Pogonip limestone, 2,700 feet thick, underlies the Eureka quartzite, the westward continuation of the Ogden. The Pogonip represents, in its basal portion, the transition beds from the Upper Cambric, but corresponds mostly to the Beekmantown of eastern North America. Beneath it are 6,200 feet of fossiliferous shales and limestones of Cambric age. Here, as in the eastern region, succes-

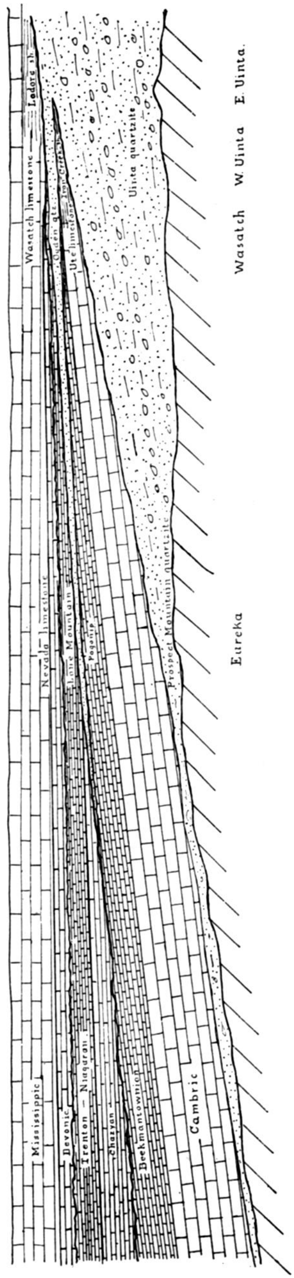

Fig. 6.—Diagram showing the relationships and overlaps of the Paleozoic strata west of the Rocky Mountains.

[1] Berkey, *Bull. Geol. Soc. Amer.*, Vol. XVI, pp. 517–30.

sively higher beds appear beneath the quartzite in the direction of the retreat, indicating continuous deposition during the slow regressive movement of the sea, this being checked as the localities successively emerged.

A widespread negative diastrophic movement is thus shown to have taken place over the whole of the North American continent, accompanied and followed by the spread of subaërial clastics over most of the area. At least 2,500 feet of calcareous strata were deposited in the non-emerging areas, and most of this constitutes the depositional equivalent of the retreatal movement (see map, Fig. 3).

The Beekmantown faunas.—The Beekmantown faunas are, so far, best known from the Lake Champlain region, the Mingen Islands, and the Newfoundland section. The Lake Champlain region, including the Phillipsburg section of the Canadian extension, has furnished a considerable number of species. Its distinctive character will be seen on consulting published lists.

The Pogonip limestone of Nevada contains mostly species unknown outside of this formation in the West, though a number of them have been referred by Walcott to eastern species, largely Trenton and Chazy types. In almost all such cases, however, the identification is provisional, and regarded by Walcott himself as doubtful. There is nothing in the character of the fauna which positively demands its reference to either the Chazy or Trenton, as has been done.

GRAPTOLITE FACIES OF THE BEEKMANTOWNIAN

In the Hudson and St. Lawrence valleys the Beekmantown is represented by the lower portion of the Hudson River shales, above the beds with *Dictyonema flabelliformis*. Some 340 feet of strata appears to be referable to this series, of which the lower 300 feet constitutes the first and second Deepkill zones, synchronous with the Upper Point Levis zone of Canada and the St. Anne zone of Newfoundland. Here the genera Chlonograptus, Goniograptus, Tetragraptus, and Phyllograptus (*P. anna*), with *Didymograptus bifidus*, characterize a succession of zones recognizable in various parts of the world. The upper forty feet of this series (third Deepkill zone)

is characterized by *Diplograptus dentatus* and *Cryptograptus antennarius*. This zone has been correlated by Ruedemann with the Chazy limestones of the Champlain region, but it probably is also referable to the Beekmantown, since most of its characteristic types occur in the Upper Arenig of Great Britain. The world-wide distribution of these graptolite faunas suggests that they were dispersed by strong currents sweeping through an open channel along the inner or western side of an Appalachian continent and its New England extension (Taconia). The fauna was most likely spread from Australia by strong currents passing up the west coast of South America and entering the Appalachian synclinal trough, along which it flowed northeastward to Newfoundland. Northwestward of this zone of mud-deposition we find the limestone of the Beekmantown grading down, by the addition of quartz grains, into the basal quartz sand, without intervening mud deposits (see map, Fig. 2).

With the progress of Beekmantown retreat the channel was closed, a land bridge connecting Taconia with Laurentia. Thus the mud deposition was checked and only a moderate thickness of Beekmantown strata of this type was formed. This represents, therefore, largely the lower part of the Beekmantown. As has been stated, it is probable that the Chazy is unrepresented by deposits of mud, the channel remaining closed until the end of that period, when it reopened through the progress of Chazy transgression, and the Normanskill beds, with a late Chazy (Lowville) and Black River graptolite fauna, were formed. In spite of some similarities, the *Diplograptus dentatus* and the *Coenograptus gracilis* zones are quite distinct, the important genera, Odontocaulus, Thamnograptus, Corynoides, Azygograptus, Leptograptus, Nemagraptus (Coenograptus), Dicellograptus, and Dicranograptus, appearing suddenly. In like manner, the characteristic Beekmantown genera, Dendrograptus, Goniograptus, Loganograptus, Dichograptus, Tetragraptus, Phyllograptus, and Didymograptus, continue through the third Deepkill zone, only the last of them extending into the Normanskill zone. Certain long-lived genera, Desmograptus, Diplograptus, Clonograptus, Climacograptus, and Cryptograptus, begin in the third Deepkill zone and extend through all or most of the remaining Ordovicic. Of the genera in common between the third Deepkill and the Normanskill,

Didymograptus is represented by three species,[1] all common in the Normanskill, and all distinct from those of the lower horizons, where eighteen species are recorded. Of the genera beginning in the third Deepkill, or Point Levis zone, Climacograptus has only one species in the lower zone, which is not known above that zone, while there are thirteen species, most of them abundant, in the Normanskill; Cryptograptus has one species in the lower and two others in the higher zone, common in each case; Desmograptus has two species in the lower and one in the higher, the latter rare; Diplograptus has four species in the lower and thirteen in the higher horizon, all distinct; while Clonograptus has two rare species in the lower and nine in the upper, mostly common. It is thus seen that there are no species in common between the two zones, and the most characteristic genera of each are unknown or rare in the other. On the other hand, six out of the twenty-four species listed by Ruedemann for the third Deepkill zone, or 25 per cent., occur also in one or both of the lower zones. Its relationship to that and distinctness from the Normanskill zone thus becomes evident. The forty feet of the third Deepkill zone probably represents the last deposits in an already shoaling and contracting channel before interruption took place, this break continuing to the end of Chazy time, when a new graptolite fauna came into existence.[2]

On the whole, the Beekmantown represents one of the large stratigraphic divisions of the Ordovicic of North America. Its fauna is essentially a unit, and although the succeeding Chazy fauna is in part, at least, derived from the Beekmantown, its distinctness is nevertheless marked. The Beekmantown corresponds to a great negative diastrophic movement, with the exception of the lower portion, and its thickness (2,500 feet where fully developed) shows that it represents fully one-third of the entire Ordovicic series, and presumably represents one-third of Ordovicic time. From this it follows that the Beekmantown alone represents the Lower Ordovicic in North America, the Middle Ordovicic beginning with Chazy deposition. The term *Beekmantownian* has therefore been proposed as the North American equivalent of Lower Ordovicic, while the

[1] Varieties are here classed as species.

[2] See Ruedemann, *Graptolites of New York*, Vols. I and II.

term Canadian becomes obsolete. The *Beekmantownian* corresponds essentially to the *Arenigian* of England and its continental equivalent.

B. THE MIDDLE ORDOVICIC OR CHAZYAN

In its maximum development, the Chazy shows nearly 2,500 feet of limestones, many portions of which are highly fossiliferous. An apparently complete development of this series, resting with conformity upon the Beekmantown, is described by Collie from Center County, Pennsylvania. Here 2,335 feet of dolomitic limestones, with fossils poorly preserved, succeeds the Upper Beekmantownian; and above this is 235 feet of fossiliferous limestones of Upper Stones River (Upper Chazy) age, succeeded in turn by the Black River. Sedimentation seems to have been continuous throughout, and this section may therefore be regarded as typical of the Mid-Ordovicic in its entirety. In southern Pennsylvania, Stose reports a disconformity and hiatus between the Beekmantown and Chazy (Stones River) limestones. The latter are from 800 to 1,000 feet thick, and are succeeded by the Chambersburg limestone (100 to 600 feet thick), which carries an Upper Chazy and Black River fauna. Continuous deposition seems to have obtained between the two series. In the Lake Champlain region, a hiatus also exists between the Beekmantown and Chazy, with the result that only about 900 feet of Chazy occurs in this region below the Black River beds. In western Newfoundland at least 2,000 feet of strata is referable to this series, the succession being conformable. Here, however, the upper limit of the Chazy is not known, the highest bed (P) being succeeded by continental sediments of much later age.

In the Arbuckle Mountains the hiatus between Beekmantown and Chazy is marked by a sandstone, and only the upper 2,000 feet of the Chazy (Simpson) is shown, followed by Black River. The Chazy is absent in the Mohawk Valley, except for a few feet of Lowville which lies disconformably upon the eroded surface of the Lower Beekmantown (Little Falls dolomite), and is conformably succeeded by the Black River. In the Black River Valley, at Watertown and northward, the sedimentation from Lowville to Black River is continuous and gradual. Cushing[1] finds in the Theresa quadrangle

[1] *Bull. Geol. Soc. Amer.*, Vol. XIX, pp. 155–76.

from 115 to 215 feet of strata beneath the Black River, and resting disconformably upon the Lower Beekmantown (Theresa formation), which, with its basal sandstone (called Potsdam by Cushing), has a maximum thickness of 140 feet. Cushing restricts the term Lowville to the upper 75 to 85 feet of pre-Black River strata, separating the lower part, on paleontologic grounds, as the Pamelia limestone. At Lowville and elsewhere this series overlaps the Beekmantown, resting with a basal sandstone upon the crystallines. The Pamelia fauna is an Upper Stones River fauna, according to Ulrich, while the fauna of the Lowville is compared with that of the Upper Chazy.[1]

In the Canadian region, only Upper Chazy (Lowville and possibly the Pamelia equivalent) is present. In a number of localities it rests directly upon the pre-Cambrics, generally with a basal sandstone (St. Mary's sandstone). In some cases, however, lower beds (Beekmantown, with basal sands) have been reported. In Minnesota and Wisconsin the Upper Chazy is called Stones River, though it represents only the upper part of the Stones River formation of Safford's Tennessee section where the thickness is 360 feet. The Minnesota beds are 32 feet thick and are probably the exact equivalent of the Lowville of New York, though the fauna is stated to be more like that of the Pamelia. The relation of these beds to the underlying St. Peter sandstone is significant, since the contact is perfectly conformable and gradational. Moreover, Stones River fossils (*Hormotoma gracilis*, *Lophospira perangulata*, etc.) are found in some of the upper beds of the St. Peter, showing that with the advent of the Chazy sea, the sand dunes of the St. Peter desert were incorporated as basal sands in the overlying formation. This meant, of course, a slight reworking of the sands by the encroaching sea. That this reworking did not reach to the bottom of the St. Peter, at least not in all cases, is shown by the persistence of the folds and faults in the lower beds, whereas they are absent in the upper (see Fig. 4). A comparison of sections shows that in general lower beds of Chazy age appear progressively above the St. Peter as we proceed southward and eastward. The relationship of these beds to the St. Peter has not been discussed in detail, but it is certain that in some localities, at least, the gradation observed in Minnesota obtains. The relation-

[1] See Cushing, *loc. cit.*

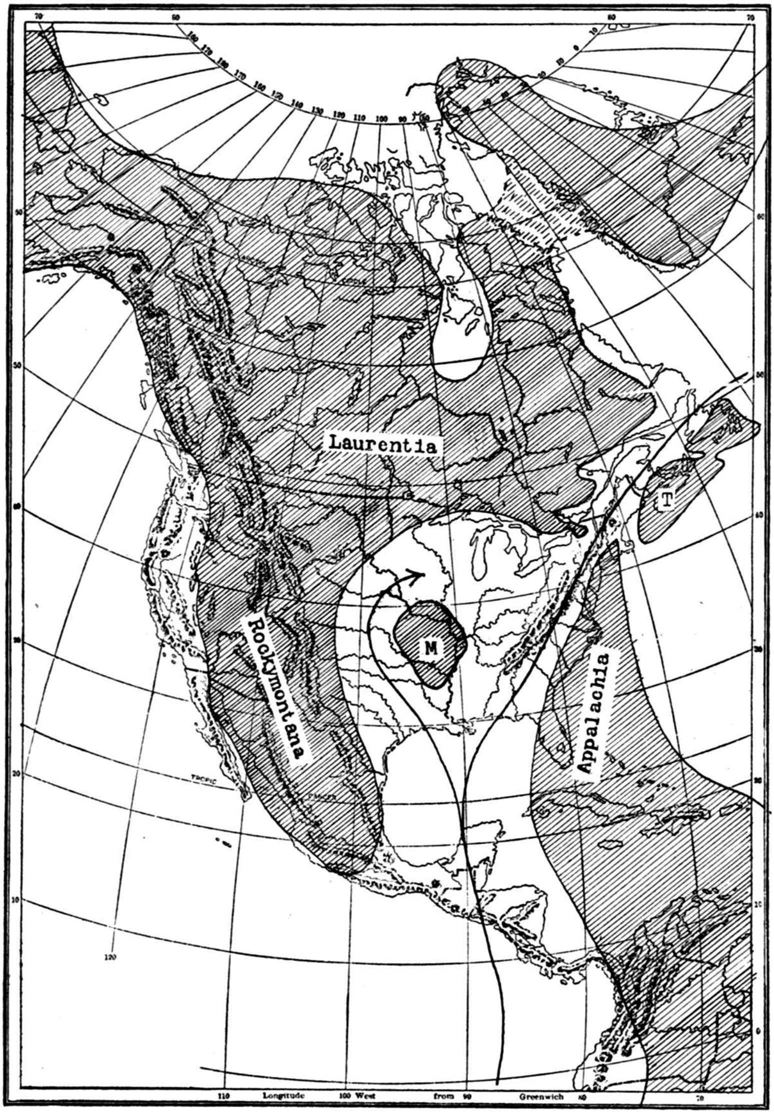

Fig. 7.—Paleogeographic map at the end of Chazy time and the probable currents. M, Ozark Island, the remains of Mississippia T., Taconic Island.

ship is, accordingly, that of a progressively overlapping transgressional series to its basal bed, and this is the interpretation favored by all the sections. The Chazy was, in fact, characterized by a transgressive or positive diastrophic movement throughout (barring possible minor oscillations), and therefore only the higher beds are found in the region of late submergence. The thickness of the formation beneath the Black River, forms in general a reliable guide to the division of the Chazy represented, though of course there may be discovered some minor disconformities which would vitiate detailed correlations made on this basis in a given region.

No unquestionable Chazy beds have been reported from the Pacific region, where the Trentonian seems to rest directly upon the Eureka quartzite in Nevada, and either Siluric or Devonic succeeds the Ogden quartzite of the Wasatch, with Mississippic beds succeeding the same in the Uintas. The west coast transgression was, therefore, less pronounced, the Nevada region remaining still uncovered at the end of Chazy time (see map, Fig. 7). If Chazy beds occur in the West, they must be sought for in western Nevada and California. It is, of course, impossible to say how much has been removed by late Ordovicic erosion. It is not improbable that the Chazy extended east of Eureka, Nev., but was removed again in Upper Ordovicic time.

The Chazy fauna.—At the beginning of Chazy time, the Champlain gulf was entirely distinct from the Appalachian gulf, there being a land connection between the Laurentio-Mississippian continent and the united Appalachia and Taconia, or Ancient New England continent (see map, Fig. 3). The faunas were thus to a large extent distinct, representing, in fact, the Atlantic and the southern type. The southern type was, in general, the Stones River type of fauna; the character of which may be seen by consulting published lists. The Atlantic type is seen in the fauna of the Champlain basin, which admits of a threefold division, a lower (Div. A) with *Orthis costalis*; a middle (Div. B) with *Maclurea magna*; and an upper (Div. C) with *Camarotoechia plena.*

That these two types of faunas were not wholly distinct in middle and later Chazy time is shown by the occurrence of true Champlain species of Mid-Chazy age, including *Maclurea magna* in the middle

portion of the "Stones River beds" of southern Pennsylvania; and of Upper Chazy species, including *Camarotoechia plena*, in the Chambersburg limestone of the same region. Whether this implies an Appalachian extension of the Champlain gulf or a connection with the Atlantic in the southern part of North America must be determined by further detailed study. It is probably true, however, that the open passage along the west border of Appalachia and Taconia, through which the mud-bearing currents swept in early Beekmantown time, and which formed the route of dispersal for the graptolite fauna of that age, was not re-established until late Chazy or Black River time. This accounts for the slight development of the graptolite-bearing shales referable to the Chazy in the Hudson and Levis series. The disconformity which represents this interruption would probably be difficult to trace in strata of such similar lithic characters.

THE BLACK RIVER FORMATION

This formation is widespread, having been traced by its fauna from the Champlain Valley to the upper Mississippi and southward to Oklahoma and the Appalachians. Over this area it forms an excellent datum plane from which correlation of overlying and underlying formations becomes possible. Its thickness is never very great; it is only 7 feet in the type region, at Watertown, N. Y., 50–60 feet in Minnesota, less than 100 feet in Oklahoma, 90 feet in southern Pennsylvania, and 70 feet in the Champlain Valley. Faunally, it represents a transition between the Chazy and Trenton, as will be seen by consulting published lists. Its classification with either the Chazy or the Trenton is therefore permissible. Since the formation represents the unchecked continuance of the transgressive movement initiated at the opening of Chazy time, its classification with that series of strata as Mid-Ordovicic is perhaps most desirable.

THE NORMANSKILL BEDS AND FAUNA

The Normanskill shales are generally regarded as representing the shale facies of the Lower or Middle Trenton. Ruedemann, in his recently published monograph parallels them with the *Lowville, Black River*, and *Lower Trenton.*[1] In Rysedorf Hill, the shale includes a conglomerate, the pebbles of which, regarded as nearly syn-

[1] *Graptolites of New York,* Part II.

chronous with the shale, carry a Lowville–Black River–Lower Trenton fauna, with some elements (*Christiania trentonensis*, *Ampyx hastatus*, Remopleurides, Sphaerocoryphe, Cybele, etc.) suggesting a geographic connection with the European sea of that time. The typical graptolite fauna of the Normanskill includes more than 60 species in all, though the widely distributed forms are much fewer. The more constant and characteristic species comprise: (1) *Coenograptus* (*Nemagraptus*) *gracilis;* (2) *Dicellograptus sextans;* (3) *D. divaricatus;* (4) *Dicranograptus furcatus;* (5) *D. ramosus;* (6) *Diplograptus foliaceous;* (7) *D. angustifolius;* (8) *Climacograptus parvus;* and (9) *C. bicornis*. Of this list, Nos. 1, 2, 4, and 8 are the most characteristic index fossils of this zone. *Didymograptus sagitticaulis*, Gurley, and *Climacograptus scharenbergii*, Lapw, may also be mentioned as characteristic though less widely distributed forms.

Besides the numerous localities along the Hudson and St. Lawrence valleys, this fauna is known from Maine and New Brunswick. In the Appalachian region it is definitely known only from New Jersey and from Bebb County, Alabama; it is also doubtfully identified from western Virginia and eastern Tennessee. It has been found in Arkansas and the Ouachita Mountains of Oklahoma; in southern Nevada (Belmont and Letson peak); and in the Kicking Horse Pass of the Rocky Mountains of British Columbia. It is also known from New South Wales and Victoria in Australia; and from southern Scotland, Scania, and France.

The distribution of this fauna is such as to suggest an eastern and a western land mass (Appalachia and Rockymontana) of low relief, with currents of the Gulf Stream type sweeping along their inner borders and distributing the graptolites, which became entombed in the muds that accumulated in these channels of moderate depth. The division of what was probably a single great current, sweeping north along the South American coast, and carrying the graptolites from Australia, was probably due to the existence of an Ozarkian island or Archipelago, along the borders of which, as in Arkansas and Oklahoma, were deposited some of these black muds. One arm of the divided current swept along the east coast of Rockymontana to the Arctic Sea of Alaska; the other along the west coast of Appalachia, past a Newfoundland island, and across the North Atlantic

Fig. 8.—Paleogeographic map at the end of Trenton time, showing second maximum transgression in the Ordovicic. The currents are indicated for Black River time. ⊕ indicates distribution of B. Normanskill graptolites.

to northern Europe (see Fig. 8). Within the protected interior sea, limestones (Upper Stones River and Black River) accumulated. Limestones accumulated also along the shores of Laurentia (Canadian shield) in the St. Lawrence channel, the two types of sediment and faunas thus occurring side by side. There is no need for postulating a dividing ridge in this channel, for the faunas and sedimentation would remain different as long as the different physical conditions persisted.

In Great Britain and elsewhere in Europe the zone of *Coenograptus gracilis* forms the summit of the Middle Ordovicic. The next succeeding zone (Hartfell shales of the Moffat district) is of Upper Ordovicic or Caradocian age. This begins with the zone of *Dicranograptus clingani*, which in North America is represented by the Magog shales or *Diplograptus amplexicaulis* zone, which succeeds the Normanskill beds.

The diastrophic movement, which in North America resulted in the emergence of most of the continent at the end of Lower Ordovicic time, was likewise marked, though to a less extent, in Europe. Lamansky has recently shown[1] that between Baltic Port and the banks of the river Volkov, the Lower Ordovicic beds (Etage B) show the progressive off-lapping structure characteristic of a retreatal or beveled-off series of sediments. At Baltic Port only the *Megalaspis planilimbata* zone (BIIα) occurs. Farther east, at Reval, the higher *Asaphus bröggeri* zone (BIIβ) and a part of the *Asaphus lepidurus* zone (BIIγ) have appeared. In the extreme east of the gouvernement of St. Petersburg, on the Volkov, the whole of BIIγ, and the *Asaphus expansus* zone (BIIIα) have come in above the others. The line of disconformity and erosion is marked by slight irregularities, by glauconite, iron oxide, and phosphate concretions, rarely by siliceous sediments. Above the erosion plane, the beds of BIIIβ and BIIIγ (zones with *Asaphus raniceps* and *Asaphus eichwaldi*) show progressive overlapping, the latter being represented only by clastic material at Baltic Port. Above these lies the Echinosphaerites limestone C, which shows continued westward overlapping.

[1] Lamansky, W., "Die ältesten silurischen Schichten Russlands," *Mém. du Comité Geol.*, N. S., Livr. XX, 1905.

The regressional movement here indicated appears to coincide with that of North America, but the transgressive movement seems to have begun somewhat earlier, unless the Lower Ordovicic is regarded as ending with the *Asaphus expansus* zone.

C. THE UPPER ORDOVICIC OR TRENTONIAN

Most current classifications of the Ordovicic formations of North America unite the Black River and Trenton limestones under Clarke and Schuchert's term Mohawkian, which is made synonymous with Middle Ordovicic. As we have seen, the Middle Ordovicic is represented by the Chazyan, which in its maximum development includes some 2,500 feet of limestone strata, and is therefore comparable in

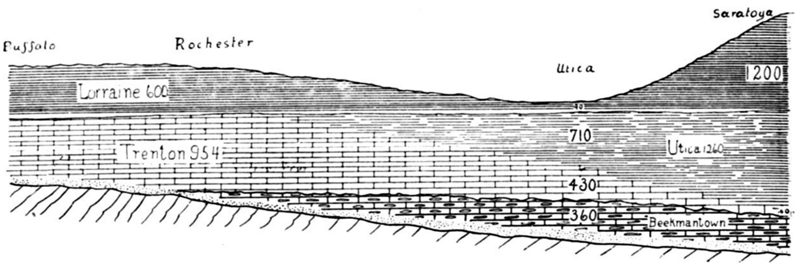

Fig. 9.—Diagram showing the relationships of the Ordovicic strata of New York, between Saratoga and Buffalo.

magnitude and, inferentially, in time value, to the Beekmantownian or Lower Ordovicic. The fauna of the Chazyan is, moreover, distinct from both preceding and succeeding faunas, and the natural dividing-line between the Middle and the Upper Ordovicic is shown, by paleontologic, stratigraphic, and diastrophic reasons, to be within or above the Black River horizon; a division coinciding with that made in the European series. The Trenton limestone of America is not a stratigraphic unit, but, as has been repeatedly demonstrated by Ruedemann and noted by many observers, it is the limestone phase of a series which elsewhere is in part or mostly represented by Utica shale. In the Mohawk Valley the dividing-line between Utica and Trenton is a line constantly rising to the west, the transition being in some cases abrupt, though probably in most cases it is gradual. Ruedemann has pointed out the progressive increase in thickness

westward of the limestone, and corresponding decrease in the shale; the former increasing from 40 feet at Saratoga to 430 feet at Utica, and to 954 feet at Rochester, while the latter decreases from 1,260 feet to 710 feet to probably zero over the same localities (Fig. 9). In the South Mountain region of southern Pennsylvania, the Chambersburg limestone of Stones River, Black River, and Lower Trenton age is succeeded by 1,000 feet of gray fossiliferous and dark bituminous shales, with intercalated limestone members in the basal portion which carry a Lower Trenton fauna. The shales contain *Leptobolus insignis*, *Triarthrus becki*, and Utica graptolites, and are succeeded by a sandstone with the fauna of the Eden beds of the Cincinnati region, formerly identified as Utica, but now regarded as younger than that formation. In central Pennsylvania, some 600 feet of Trenton succeeds to Black River, and is followed by 650 feet of Utica shale. In this zone also we have some typical Trenton species, such as *Dalmanella testudinaria*, *Isoteles platycephalus*, etc., associated with *Triarthrus becki* and other Utica species. The various sections clearly show that along the western border of the Appalachians, dark graptolite shales continued to form in Upper Ordovicic time, while westward from this the Trenton limestone represents the calcareous phase of the Utica-Trenton series (see map, Fig. 8).

THE TRENTON–UTICA GRAPTOLITE FAUNAS

The Normanskill fauna is succeeded by that of the Magog shales or zone of *Diplograptus amplexicaulis*—the upper Dicellograptus zone of Gurley. This represents, according to Lapworth, highest Llandeilo or lowest Caradoc, and forms a transition to the true Utica fauna. Many of its species are characteristic of the Hartfell shales (Caradocian) of southern Scotland, though others are equally characteristic of the Normanskill and Glenkiln shales. Ruedemann regards this fauna as a relict of the preceding one.

> The Didymograptidae have vanished entirely, and the Dicranograptidae almost; only the long range forms, *Dicranograptus ramosus* and *nicholsoni*, are still observed, and the Diplograptidae . . . . hold now almost entirely the field, with the genera Diplograptus, Climacograptus, and Cryptograptus.[1]

The fauna is best developed near Quebec and at the north end of Lake Memphremagog, only fragmentary representation occurring

[1] *Op. cit.*, II, 30.

in New York. The fauna is rapidly changing, the true Upper Ordovicic faunas are appearing, and soon the typical Utica fauna, with *Glossograptus quadrimucronatus*, *Climacograptus typicalis*, *Corynoides curtus*, and, less frequently, *Leptograptus flaccidus*, *Dicranograptus nicholsoni*, and *Climacograptus putillus* is established. The association of typical Utica graptolites with characteristic Trenton limestone fossils, as *Trocholites ammonius*, *Cameroceras proteiforme*, and *Schizocrania filosa*, bears on the previously discussed question of the synchroneity of the Utica and Trenton.

Climacograptus typicalis, the typical Utica species, is reported by Winchell and Ulrich from the Fusispira and Nematopora beds of the middle Galena of Minnesota. Since the Galena of that section follows directly upon the Black River, this occurrence is only a short distance above the base of the Trenton, which is thus indicated to be the western limestone equivalent of the Utica shale of the east. As already noted Ruedemann has cited abundant evidence of the gradual westward extension of the successively higher zones of the Utica, and the replacement of the limestone phase (Trenton) by them. The Galena-Trenton limestone of the Lake Winnepeg region contains *Dictyonema canadense* (Whiteaves), *Thamnograptus affinis* (Whiteaves), and the typical Utica species, *Climacograptus typicalis* (Hall). Whiteaves concludes that the Galena-Trenton of Lake Winnepeg "most probably represents the whole of the Utica and Trenton formations, inclusive of the Galena."[1]

THE CINCINNATI GROUP

This is the upper calcareous phase of the latest Upper Ordovicic, and comprises, in ascending order, the Eden, Maysville, and Richmond. The Eden was formerly correlated with the Utica, but the underlying Trenton mainly represents that formation. The Eden is in part equivalent to the Frankfort shales, though the occurrence of *Climacograptus typicalis* in the Eden strata would favor its former correlation with the Utica. The Maysville represents later Lorraine as developed in New York, though the fauna, being that of a calcareous facies, is markedly different.

Ulrich has reported a disconformitv at the base of the Eden, in the Cincinnati section, but this, if it exists, does not appear to be

[1] Quoted by Ruedemann, *op. cit.*, II, 28.

of great importance. It certainly does not represent Utica shale. There is, however, a marked and widespread disconformity between the Lower and Upper Trentonian, the late Richmond resting on Trenton or even earlier beds. This is observed throughout the Rocky Mountain area, the upper Mississippi region, and to a less extent in other sections. It signifies a retreat of the sea, probably at the end of Trenton time, and a return during late Richmond time.

THE TRENTON–CINCINNATI FAUNAS

While on the whole the faunas of the Trenton limestone and of each one of the three divisions of the Cincinnati group are sufficiently distinct, so that it is not difficult to recognize the exact horizon of each by a careful analysis of the fauna, there is, nevertheless, a unity in these faunas, which shows their unmistakable relationship to one another and their distinctness from the preceding faunas. It is this broad similarity of faunas, together with the distinctness from the preceding faunas, the intimate relation of the limestone to the Utica shale which it replaces, and the moderate thickness of the formation in its best development, as compared with that of the Chazy and Beekmantown, that has led me to place the Trenton limestone in the Upper Ordovicic. In England, the Upper Ordovicic or Caradocian (Bala) is characterized by the same faunal elements which here appear for the first time. The more common species characterizing the Upper Ordovicic from the Trenton up, and occurring in most if not all of its beds, include *Rafinesquina alternata*, *Plectambonites sericea*, *Dinorthis subquadrata*, *Plectorthis plicatella*, *Dalmanella testudinaria*, *Platystrophia biforata; Protowarthia cancellata*, *Liospira micula*, *Clathrospira subconica*, *Trochonema umbilicatum*, *Cameroceras proteiforme*, *Calymmene callicephala*, *Isoteles gigas*, *I. maximus*, and *Ceraurus pleurexanthemus*.

Some of these species begin in the Black River or even in the Upper Stones River, but they are most characteristic of the higher horizons.

THE CONTINENTAL PHASE OF UPPER ORDOVICIC TIME

The later epochs of Upper Ordovicic time were characterized by continental or non-marine sedimentation in the Appalachian region. The earliest of these is the conglomeratic and quartz-sand

series found directly overlying the fossiliferous marine Ordovicic of southern Pennsylvania, and generally classed by Pennsylvania geologists as "Oneida." This is a gray to white, rarely red, conglomerate and quartz sandstone with rounded quartz pebbles and characterized by extensive cross-bedding. Its maximum thickness today is in Bald Eagle Mountain, near Tyrone City, Blair County, Pennsylvania, after which locality I originally named it.[1] This name, however, was preoccupied, and the formation under consideration is therefore called the Bald Eagle conglomerate, this ridge being due to the resistant character of this and the succeeding formation. At Tyrone the thickness is 1,319 feet, while thirty miles to the northeast, at the Bellefonte Gap, through the same ridge, the thickness is only 550 feet, and the formation is divisible into a lower hard gray sandstone without pebbles, 170 feet thick, and an upper greenish-gray somewhat ochery and micaceous sandstone with intercalated greenish shales. One hundred and sixty miles northwest from Tyrone, at Buffalo, this formation (Oswego sandstone) is 75 feet thick. It is here a white quartzite lying below the red Queenston shales, and represents only the upper layers of the gradually spreading fan of clastic sediments. In central New York the Oswego is 185 feet thick at the falls of the Salmon River. It there succeeds the Lorraine beds with perfect conformity, some Lorraine fossils extending into the lower Oswego.

There can be little doubt that these beds represent the northern and western attenuated upper beds of the Bald Eagle conglomerate of Pennsylvania, unless indeed they belong to one or more distinct fans with a source in the north.

The character of the rock, its cross-bedding, and absence of fossils indicate continental origin, and this is also shown by the nature of the overlap, which is that characteristic of river deposits. The intimate relationship between the Lorraine and the highest bed (Oswego sandstone) of this formation, indicates that the age of this formation is Lorraine. The Bald Eagle conglomerate is everywhere succeeded by the red shales and sandstones of the Juniata formation. In southern Pennsylvania this overlaps the preceding formation and rests directly upon the Eden sandstone. The forma-

[1] *Science*, N. S., Vol. XXIX, p. 355.

tion here contains remnants of the Lorraine fauna with *Byssomichia radiata* and other types. These beds are clearly the lower Juniata, for the base of the series is seen in contact with the Bald Eagle conglomerate not far away. The maximum thickness of the Juniata in central Pennsylvania is from 1,000 to 1,200 feet. On the Niagara, the corresponding Queenston shale is 1,100 feet thick, and it thins away almost wholly before reaching Michigan, where only a few red beds mark the summit of the Ordovicic.

The Juniata has all the characters of deposits in arid regions. The total absence of fossils, except where, at the beginning, a lagoon extended north into Pennsylvania, is a striking feature. That fossils could be preserved in the formation is proved by the occurrence

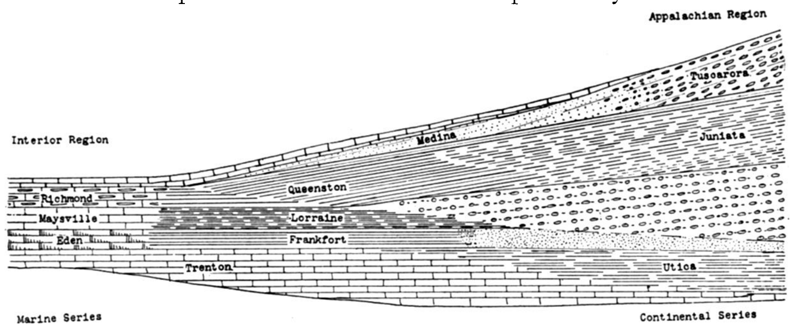

Fig. 10.—Diagram showing relationships of marine and continental upper Ordovicic and lower Siluric strata. The conglomerate beneath the Juniata is the Bald Eagle, and beneath it is the Eden sandstone.

of Lorraine species in the basal beds. Their absence from the others must then be taken as indicating that none were inclosed in the strata. This absence of fossils, together with the character of the beds, their red color, frequent mudcracks, and numerous clay slugs or "Thongallen" in the sands, and the aeolian cross-bedding, all point to a continental origin, under conditions of semiaridity and tropical climate. That the Juniata and Queenston beds are equivalent, and were formed under the same physical conditions, cannot be doubted. Their correspondence in thickness indicates an almost complete equivalency. They may, however, have distinct sources, one in the southeast and the other in the north. In western New York the Queenston shales are succeeded by the true Medina sandstones and green shales, which are partly fossiliferous, carrying a true

Niagaran fauna. This fixes the age of the Queenston and Juniata as Richmond, so far as their major portion is concerned; though, as already noted, the lower part must be considered as Lorraine (see Fig. 10).

In eastern Tennessee a second deposit of red sands of this period forms the Bays sandstone. This is from 1,100 to 1,300 feet thick in its maximum development near Loudon, but thins away by overlap in all directions. In some localities, as at Walker Mountain, it is fossiliferous, carrying the late Lorraine fauna with *Byssonychia radiata*, *Modiolopsis modiolaris*, etc. Wherever the contact with the underlying Sevier shale is exposed, it is seen to be a gradational one, the fossils extending part way up into the red beds. The basal white bed, comparable to the Bald Eagle conglomerate, if it ever existed here, was overlapped by the Bays, the portion east of the overlapping edge having been removed by erosion. The Bays may be regarded as an independent fan, or group of fans, of red sedimentation with a distinct center of supply.

The correlation of this series of continental sediments with the contraction of the sea known to have occurred in Upper Ordovicic time has not yet been attempted. It is not improbable that the initial uplift of the land which caused the retreat of the sea, also initiated the strong river-activities which resulted in the formation of the Bald Eagle conglomerate and sandstone. This probably corresponded to the period of folding of the Ordovicic and earlier strata in New England and northward. If that is the case, the emergence was probably post-Trenton, falling in early Lorraine (Frankfort or Eden) time and extending toward the end of Lorraine time. The period of red sedimentation in the east may have coincided with the period of erosion in the upper Mississippi and Rocky Mountain areas, and deposition of the Richmond in the narrow interior basins. The late Richmond expansion may coincide with the climatic change indicated by renewed river deposits of white quartzose material.

D. THE LOWER SILURIC OR NIAGARAN

The following divisions of the New York Niagaran are in common use as the North American standard: Guelph, Lockport, Rochester, Clinton.

The Clinton of the best known section, that of western New York, begins with the true or Upper Medina, which, along the Niagara River, admits of a number of subdivisions, which are, however, of only local significance.[1] The total thickness is nearly 125 feet, with 25 feet of white quartzose sandstone (Whirlpool sandstone) at the base, and about 8 feet of a similar sandstone at the top. The middle series consists of red sandstones and green and gray sandstones and shales. The red sandstones generally show aeolian cross-bedding and appear to have accumulated above water. The green sandstones and shales are fossiliferous. The white Whirlpool sandstone exhibits beach features,[2] and probably marks the advance of the sea, though it is likely that the sand was originally dune sand, as suggested by A. W. G. Wilson.

The fossils are generally most abundant in the shales and thin-bedded sandstones. The heavy-bedded sands are either free from fossils or have only scattered shells of Lingulae. At Lockport and elsewhere some layers are crowded with gastropod shells. The characteristic fossil, *Arthrophycus harlani* is everywhere in New York restricted to the upper beds just below the upper white sandstone.

The fossils so far obtained from the Medina are: *Arthrophycus harlani* Conr.; *A.* sp.; *Daedalus* several species; *Scolithes verticalis* Hall; *Dictyolithes beckii* (Conr.); "*Fucoides*" *auriformis* and "*F.*" *heterophyllus; Holopea fragilis* Hall; *Lingula cuneta* Conr.; *Whitfieldella oblata; Camarotoechia* sp.; *Uncinulus stricklandi* (Sowerby); *Plectorthis medinaensis* sp. nov.; *Rhipidomella* sp.; *Pentamerus* sp.; *Modiolopsis orthonota; M. primigenius; Pterinea cf. emacerata; Pleurotomaria pervetusta* Conr.; *P. littorea* Hall; *Holopea* (?) *conridea; Bucanopsis trilobatus* (Conr.); *Oncoceras gibbosum; Orthoceras* sp.; *O. multiseptum* Hall; *Ascidaspis* sp.; *Dalmanites* sp.; *Isochilina cylindrica* Hall.

This is a Lower Siluric fauna, and favors more especially the Clinton and Rochester faunas. It is so far known only from western New York, with the exception of *Arthrophycus harlani,* which is widely distributed. In western New York this species occurs at the top of a heavy-bedded unfossiliferous sandstone with an aeolian type

[1] See *Bull. 45, New York State Museum,* pp. 88–95.

[2] Fairchild, H. L., *Amer. Geol.,* Vol. XXVIII, 1909.

of cross-bedding; and just below the upper white quartzite. In east-central New York it is found at the base of the Oneida conglomerate, which is the approximate equivalent of the upper white sandstone of Niagara. In the Appalachians, it is found mostly in the upper part of the Tuscarora and Clinch sandstones, the stratigraphic equivalent of the Medina. Sarle[1] has recently interpreted this structure as due to worm borings. So far as I have observed in the field, the raised ridges of this fossil always occur on the under side of the sandstone layers, representing, therefore, the relief molds of grooves generally formed in the clays beneath. These grooves had a median ridge and a regular succession of transverse ridges separated by broad concave grooves. A similar structure, known as Climatichnites trails, but of a much broader type, occurs in the Potsdam sandstone of New York. Woodworth[2] has suggested that it represents the trail of an animal comparable to some extent to modern Chiton.

There are no known remains of organisms in the Medina or Clinton capable of making such an impression, and the organism which made it either had no parts capable of preservation or else it was a terrestrial type frequenting the shores and sandy wastes, where it left its trail in the mud, but not its remains, just as the Triassic Dinosaurs left their footprints but seldom their skeletons.

The Tuscarora has a thickness of 820 feet in Logan's Gap, Jack's Mountain, Mifflin County, Pennsylvania, but thins perceptibly westward and southward, being 400 to 500 feet thick in Bald Eagle Mountain and 287 feet in Wells Mountain and the Pennsylvania-Maryland line. This thinning appears to be due to failure of the lower beds, showing a true case of non-marine progressive overlap. In New York, the upper part is represented by the true Medina, which has a thickness of 125 feet, and begins and ends with a pure white quartz sandstone. More strictly speaking, the upper white sandstone alone represents the true Tuscarora, but the lower beds, still partly red, and the shales, probably are the equivalent of the lower reddish sandstones and greenish shales underlying the true white Tuscarora, and sometimes referred to the Upper Juniata. The Oneida conglomerate of central New York, 40 feet thick, is likewise

[1] *Rochester Acad. of Sci. Proc.*, 1906, No. 4, p. 203.

[2] New York State Pal. Rep., 1907, *Bull. New York State Museum, No. 69*, p. 959.

the representative of the upper part of Tuscarora, though it may have had a more local origin.

All of these beds, including the basal white Bald Eagle formation, belong to the much-washed and reworked type of continental sediments, in which concentration of the indestructible quartz had been brought about by long exposure, resulting in the decomposition of all the other minerals, and the removal of the resultant clay and dust by wind and running water.

The Clinton shales succeed the Oneida conglomerate in Oneida and Herkimer counties, New York, and the Upper Medina quartzite in western New York. In the southern Appalachians, the series is largely composed of sandstones (Rockwood), highly impregnated with iron, and often containing beds of workable iron. It is generally succeeded by late Siluric (Monroan) or by Helderbergian or later beds, there being a pronounced disconformity at the summit of the Rockwood throughout. That part of the series in Virginia is of continental origin is indicated by the general character of the rocks, but marine intercalations are not uncommon. In some cases in eastern Tennessee the iron ore itself is fossiliferous, having replaced a marine limestone. In such cases the bulk of the formation is shale. In no case is the original thickness preserved since the formation is everywhere bounded above by an erosion plane. In northern Virginia today the thickness is 750 feet (Piedmont folio), and not over 400 feet in southern Virginia. In southern Tennessee and northern Georgia it is from 1,100 to 1,600 feet thick, decreasing westward and northward. With our present knowledge of the formations, it is safe to say that the eastern sandy phase represents near-shore deposits, if not actually continental conditions, formed probably at the embouchures of several Appalachian rivers; and that westward these deltas merged gradually into true marine deposits, mainly sands and clays, with some limestones intercalated. That the Rockwood represents more than the Clinton of New York cannot be questioned. Where the series is developed in its totality, it probably represents the entire Niagaran, if not a part of the Salinan as well. Along the Alleghany front, fossiliferous shales and iron ores represent this series, with a thickness of not less than 1,000 feet, on the western branch of the Susquehanna. The lower series, 700 feet thick, consists mainly of

fissile shales, including an iron sandstone, and with Buthotrephis in the upper part. This is succeeded by 110 feet of calcareous fossiliferous shales; and this by 230 feet of fossiliferous shales and limestones with a Niagaran fauna. Above this follows 350 feet of red shales, probably representing the Upper Salina, and separated by a hiatus from the fossiliferous Niagaran shales.

In eastern New York, at Swift's Creek, the type locality for the Clinton, this formation is 226 feet thick and is followed by 5 feet of Niagaran and then by the red shales of the Upper Salina. On the Niagara River the Clinton shale with the two succeeding limestones has a total thickness of 32 feet, followed by 68 feet of Rochester shale. The total of the Niagaran, including the Guelph, is from 270 to 325 feet, as shown by borings. This is followed by Lower Salinan. In the Rochester region the Clinton has a thickness of 80 feet, including the Irondiquoit or upper limestone (17 feet), which Chadwick refers to the Rochester. The eastward thinning of the Upper Niagaran beds indicates either that these beds were eroded before the deposition of the red shales, probably during the Shawangunk epoch (see beyond); or that the Rochester-Lockport of the West is in part represented by Upper Clinton in the East. The Guelph element may never have extended to the Clinton type region, which may have been above water and so subject to erosion.

The most typical section of the North American Lower Siluric or Niagaran is found in Wisconsin, where the series exceeds 700 feet in thickness and is wholly calcareous. At the base of the series, however, in a few localities, as at Iron Ridge, occurs a remarkable iron ore, composed of flat lentils of varying size and heaped together in a mass strongly suggestive of dune history. This idea is borne out by the position of these pellets, which are not laid flat, as would be the case if they were deposited by water, but are placed in all positions. Cross-bedding and irregular wedging-out of layers and a rapid thinning away of the entire mass, further suggest such an origin. There are no fossils in the ore, and it rests upon an uneven surface of the Upper Ordovicic, with a layer of highly polished clay pebbles marking its base. The interpretation of this formation that I am at present able to advance is that of a dune of calcareous pellets of concretionary or phytogenetic origin, similar to the oölite dunes of Great Salt

Lake and other regions; and that these dunes were subsequently altered, by replacement, to iron ore.

The series of limestones overlying this basal bed, or resting directly upon the Ordovicic, is for the most part richly fossiliferous. Some of the beds, as the Racine and the Coral Beds, are characterized by reefs of Stromatoporoids and other corals, widely distributed and connected by more or less barren lime sands (calcarenytes) which resulted from the erosion of the reefs. Some beds are of shallow-water origin and bear the marks of periods of exposure, resulting in the formation of mud cracks, etc. The fauna is more or less uniform throughout, and the series represents continuous deposition, recording only minor oscillatory movements. Southward we find these beds extending through northern Illinois, Indiana, and Ohio, with a more or less uniform fauna, while further south, in the Cincinnati and western Tennessee regions, part of the limestones is replaced by shales and new faunal elements appear.

The typical Niagaran fauna.—This is to be found in the strata of the Wisconsin section and in their continuations in northern Illinois, Indiana, Michigan, and Ohio. It is an exceedingly rich fauna, and, as Weller has ably demonstrated, has many elements in common with the Mid-European Siluric. The Stromatoporoids abounded on the reefs of the Coral Beds and the Racine. They have not been much differentiated in Wisconsin, but from other sections, especially Canada and Ohio, a considerable number of genera and species have been recognized. Corals abound, especially Halysites and Favosites, while Bryozoa are most common in the shales of New York and the southern area, Fistulypora making extensive reefs in western New York. The brachiopods, except the large Pentamerus, are likewise more characteristic of the shales. Crinoids, Cystoids, and Trilobites appear to be most common in the limestones of the interior.

The Guelph fauna.—This fauna demands a special notice, because it is so distinct in its eastern manifestations. The peculiar aspect of the fauna is produced by the great Trimerelloid brachiopods (*Trimerella grandis*, *T. ohioensis*, *Monomorella prisca*, etc.); the peculiar corals Pycnostylus; the large pelecypod *Megalomus canadensis;* the gastropods *Pycnomphalus solarioides;* and the genera

Euomphalopteris, Hormotoma, and Coelidium, together with various species of Eotomaria and other Pleurotomarioids, and the remarkable *Trematonotus alpheus*. This represents a new invasion of the interior sea, probably from the rich fauna of northern Europe. In North America the physical conditions accompanying this spread of the fauna appear to have been shoaling of the water and inclosure and restriction of the interior sea. The fauna appears as early as the lower Coral Bed in Wisconsin, while the Guelph element of the Racine fauna is very marked. *Trimerella grandis*, *Megalomus canadensis*, *Pycnomphalus solariodes*, *Coelidium macrospira*, and *Sphaeradoceras desplainense* are among the species which occur in association with the rich Racine fauna. Many of the typical corals, brachiopods, and other types continue into the Guelph in Wisconsin, the fauna not differing markedly from the Racine. In New York Clarke and Ruedemann have found the Guelph fauna intercalated between the normal manifestations of the Niagaran coral fauna (Lockport), and it appears that in the Canadian type region alone does it occur in its purity.

THE ATLANTIC AND SOUTHERN NIAGARAN

The Atlantic Niagaran has generally been recognized as belonging to a distinct province separated by a land barrier from the interior sea. This is made evident not only by the distinctness of the faunas, as exhibited in the Anticosti group and the development in Maine and New Brunswick, but also by the fact that the entire interior Appalachian region contains only shallow-water or continental deposits, indicating a continuous land mass in the East. That the Anticosti fauna nevertheless communicated with the interior is shown by its occurrence in Georgia and elsewhere in southeastern United States. This occurrence represents either a distinct embayment from the Atlantic, or the fauna migrated into the interior, going around the southern end of Appalachia, which may then have been separated from South America. An invasion of the interior from the south is indicated by the fauna of the Cape Girardeau or Alexandrian[1] formation of Illinois and Missouri, and perhaps also by the fauna of the

[1] See Savage, T. E., *Amer. Jour. Sci.*, Vol. XXV (1908), pp. 431–44; Schuchert, *Jour. Geol.*, Vol. XIV (1906), pp. 728, 729.

St. Clair[1] limestone of Arkansas. The Alexandrian series of Savage contains many types unknown from the true Niagaran, some Ordovicic genera also being present (Rafinesquina, Platystrophia, Rhynchotreta, Zygospira). Few typical Niagaran species occur, but the presence of the genera Favosites, Atrypa, Whitfieldella, Homoeospira, Schuchertella, Chlorinda, and Lichas (Metopolichas) indicates the Siluric age of this fauna. It probably represents an invasion from the south before the Niagaran transgression from the north had reached the southern Illinois region. Northward, in central and northern Illinois, this fauna seems to be wanting, the true Niagaran fauna here succeeding the Cincinnatian.

The Alexandrian is succeeded disconformably by 30 to 75 feet of limestones with a Lower Niagaran fauna. A transgression is indicated by the fact that "where the formation is thinnest, it is the lower, and not the upper layers that are absent."[2] The Niagaran fauna includes: *Favosites favosus*, *Halysites catenulatus*, *Atrypa rugosa*, *Orthis flabellites*, *O. cf. davidsoni*, *Plectambonites transversalis*, *Stricklandinia triplesiana*, and *Triplesia ortoni;* which grouping, as stated by Savage, corresponds to that of the Clinton of the Dayton, Ohio, region.

The invasion of the interior by a southern fauna, in later Niagaran time, seems to be indicated by the later Siluric formations of Tennessee and possibly in part by the Louisville limestone of Indiana and Kentucky. The higher beds of western Tennessee, called by Foerste[3] the Brownsport beds, and subdivided into the Beech River, Bob, and Lobelville formations by Pate and Bassler[4] contain faunas apparently not found in the typical or northern Niagaran formations, and which are well developed in the underlying series, named, in ascending order, Clinton, Oswego, Laurel, Waldron, Lego, and Dixon.

[1] Van Ingen, Gilbert, "The Siluric Fauna near Batesville, Ark., Part I," *Schoo of Mines Quarterly,* Vol. XXII (April, 1901), pp. 318–29.

[2] Savage, *op. cit.*, p. 435.

[3] Foerste, A. F., "Silurian and Devonian Limestones of Western Tennessee," *Jour. Geol.*, Vol. XI, pp. 554–715.

[4] Pate, W. F., and Bassler, R. S., "The Late Niagaran Strata of West Tennessee," *Proc. U. S. Nat. Mus.*, Vol. XXXIV, pp. 407–32. See also Roemer, *Die silurische Fauna des westlichen Tennessee*, in which the fauna of these higher beds is described.

E. THE MIDDLE SILURIC OR SALINAN

This is typically known only from New York, Michigan, western Ontario, northern Illinois, and Ohio, and is everywhere a series of more or less calcareous shales and gypsiferous beds, with salt beds up to 100 feet in thickness. The maximum development is in central New York and southern Michigan, where it exceeds 1,000 feet in thickness. In western New York it is only 350 feet thick. The only fossils known from the beds are from the lower (Pitsford) shales, where they represent the last survivors of the Guelph. They are chiefly Eurypterids (Hughmilleria, Eurypterus, etc.) and occur in muds alternating with dolomites carrying a Niagaran fauna. The Eurypterid fauna also occurs in the mud layers in the Shawangunk conglomerate, which hardly admits of any other interpretation than deposition by torrential rivers. This would make the Eurypterid fauna a fresh-water fauna, an interpretation which best corresponds with the distribution of these fossils geologically as well as geographically. The Salina series is best understood as a desert deposit. The absence of organic remains (with the exceptions noted), known to be abundant in all modern salt deposits of sea-margin origin; the thickness of the salt beds; their limitation to circumscribed basins,[1] the red color of the lower shales, their mud cracks, "Thongallen," etc., all point to a continental origin. The absence of true marine strata of Salina age[2] and erosion of the surrounding Niagaran beds further indicate that North America was above water. The salt was derived from the marine limestones of Niagaran and earlier age.

THE GREEN POND SHAWANGUNK CONGLOMERATES AND SUCCEEDING RED SHALES

The general retreat of the sea at the end of Niagaran time was marked in the east by an uplift followed by continental sedimentation. The series began with a conglomerate (Green Pond) 1,500 feet thick in northern New Jersey, but thinning northward to 500 feet at Ellenville (Shawangunk conglomerate), to 200 feet at Rosendale, and to nothing at Rondout. Southward and westward it thins

[1] See Walther, *Gesetz der Wüstenbildung*. Lack of space forbids the full discussion of this interesting problem. It will be treated at length in another paper.

[2] The so-called marine Salina of Maryland is of Monroan age.

to 700 feet at the Delaware water gap, to 400 feet at the Lehigh, and to less southward. The thinning is by failure of the lower beds, showing this to be a true non-marine overlap, and therefore stamping the series as of river origin. The Eurypterid layers in the upper beds are probably contemporaneous with the basal Eurypterid beds of the Salina of New York. The succeeding series of Longwood shales resembles the Juniata-Queenston, and, like it, has all the earmarks of a continental series formed under semiarid conditions. They thin from 2,385 feet in New Jersey to 120 feet at Cornwall, 75 feet at High Falls (High Falls shale); and 25 feet at Rosendale, and disappear farther north. Southward they thin likewise, while westward only the upper 400 feet of the series is shown in the red Lower Salina shales of Ithaca and Syracuse, New York, where they are succeeded by salt deposition and less than 200 feet at Buffalo. Like the conglomerate, the shales thin by failure of the lower beds, i. e., by non-marine overlap away from the source of supply.

F. THE UPPER SILURIC OR MONROAN

This is typically developed in southern Michigan, Ohio, and western Ontario, where it is divisible into Lower Monroe or Bass Islands series, 500 feet thick, or more; middle Monroan or Sylvania sandstone 30 to 150 feet thick; and Upper Monroan or Detroit River series, 300 to 400 feet thick.[1] The entire series is involved in gentle folding of early Devonic age, the Dundee resting upon the eroded surfaces of various members of the series.

The Lower Monroan represents an invasion from the Atlantic across Maryland, Pennsylvania, and southern Ohio, to Michigan and probably Wisconsin. Western Ontario was involved, but apparently not western New York. The fauna is Upper Siluric, genetically related to the Manlius limestone fauna, and, like it, representing an Atlantic type. The Upper Monroan fauna, on the other hand, is of a distinct type, especially in the lower members (Flat Rock, Amherstburg, and Anderdon beds). Besides being related to the later Niagaran fauna, it has a new coral and brachiopod element suggestive

[1] See Sherzer and Grabau, *Bull. Geol. Soc. Amer.*, Vol. XIX. The full discussion of these formations and their fauna will appear in the report of the Michigan Survey.

of Devonic affinities. This is further shown by the occurrence of Panenka and Hercynella in these beds. The highest division (Lucas) is characterized by gastropods, most nearly related to late Siluric types of northern Europe.

The Amherstburg beds of the Upper Monroan appear to be the chronologic equivalent of the Cobleskill of eastern New York, several characteristic species being common to both. It represents the junction of an eastern and a western sea, and a commingling of the fauna of both. The typical Upper Monroan coral and brachiopod fauna seems to have invaded Michigan from the northwest, a somewhat similar fauna appearing near the headwaters of the Saskatchewan. In Pennsylvania the Lewistown limestone appears to represent this horizon.

The Sylvania sandstone has all the characteristics of a wind-drifted sand. Its cross-bedding is of the aeolian type, its grains well rounded, pitted, grooved, and of uniform size; there is a total absence of impurities, and all the characteristics compare favorably with those of the sands of the Lybian desert of today. It indicates a period of land condition between the retreat of the Atlantic embayment (Lower Monroan) and the Pacific invasion of Upper Monroan time.

G. THE LOWER DEVONIC

The Lower Devonic comprises the Helderbergian and the Oriskanian of Clarke and Schuchert. The Helderbergian includes the Coeymans, New Scotland, Becraft, and Port Ewen. The latter is transitional to the Oriskany, and Chadwick proposes to unite it with that formation.[1] The Coeymans is the direct depositional successor of the Manlius, there being frequently a transitional zone between them, with a commingling of the fossils. The former extent of the Coeymans can be estimated from its occurrence at Syracuse and the uniform character which it maintains in that region. This indicates that the western shore of the Helderberg sea was west of Syracuse and perhaps in the region of Buffalo. The eastern and northern limit of the formation is indicated by its mergence into shore deposits in New Jersey, and the southward overlap of the later formations,

[1] *Science*, N. S,, Vol. XXVIII, p. 347.

the Virginia, western Tennessee, and Oklahoma occurrence of this series beginning with beds carrying a New Scotland fauna.[1]

The emergence of the North American continent at the end of Siluric time was accompanied by the first pronounced doming of the Cincinnati region and basining of the Michigan area. Local oscillations seem to have preceded this, but the first great movement apparently did not occur until the end of the Siluric. Between the Michigan basin and the Cincinnati dome were formed the Wabash anticline and the minor folds of Michigan, Ohio, and Canada. When these regions were again wholly submerged in Mid-Devonic time, the deposits of this later epoch came to rest on the beveled surfaces of various Siluric members (see Fig. 11). A subsequent movement

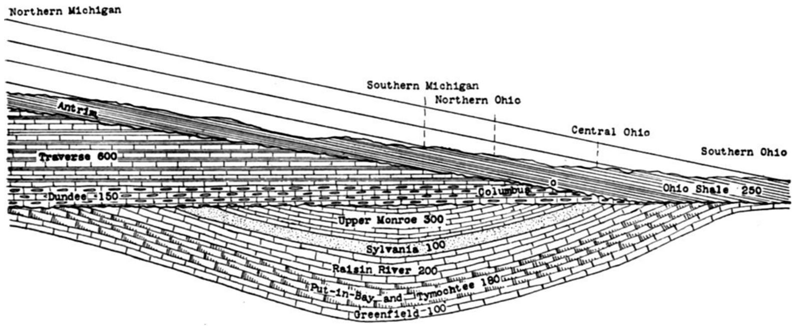

Fig. 11.—Section from northern Michigan to southern Ohio, showing the relationship of the Middle Devonic to the Siluric and of the Upper to the Middle Devonic. O = Olantangy shale.

in the same direction, at the end of Paleozoic time, threw the later beds into similar folds, while emphasizing those of the earlier series.

A marked hiatus occurs between the Helderbergian and Oriskanian. The former series is beveled, so that the Oriskany comes to rest, as it extends westward, upon lower and lower members of the Helderbergian, and finally upon the Manlius, and still farther west upon the Akron dolomite (Cobleskill). This beveling is in part due to retreatal "off-lap" but also to extensive erosion which indicates a time-period of some magnitude for the Oriskany. The depositional equivalent of this hiatus is found in the Gaspe region of Canada, where 550 feet of Oriskanian (Grand Greve limestone) follows

[1] See Grabau, *Bull. 92*, *New York State Museum.*

1,200 feet of Helderbergian (St. Albans and Bon Ami limestones), the succession being a conformable one.[1]

The Oriskany of the United States is mostly a sandstone, often of pure quartz grains, at other times calcareous. The source of the sandstone is to be sought in the sandstones of the eastern extension of the Siluric and Ordovicic formations, and perhaps in the exposures of the St. Peters and the Sylvania. It seems most likely that the distribution of the sand over eastern North America was largely effected by wind, during the long period of erosion preceding the submergence of the continent. On the westward extension of the Oriskany sea these accumulated sands were reworked and were transformed into the fossiliferous marine sands which they are found to be today. In the east, after a short period of sedimentation, an extensive accumulation of black muds occurred, forming the Esopus-Schoharie shale series. This has its greatest thickness at Port Jervis, whence it thins away in all directions, apparently by overlap. Since the source of the material was clearly in the east, and the overlap is toward the west, north, and south, the formation must be a subaerial fan. This is further indicated by the general absence of fossils, except for occasional intercalations, such as would be expected in a fan of this kind, probably rising but slightly above the level of the shallow Oriskany sea. The continuance of the Oriskany invasion is found in the spread of the limestone with the Schoharie fauna and the succeeding Onondaga submergence. During Onondaga and Hamilton time, continuous deposition and spreading of the seas went on, but at the close of the Middle Devonic, renewed emergence affected most of southern and southeastern United States, accompanied by erosion. This again was followed by the slow resubmergence, which commenced from the north and slowly advanced southward and eastward. The basal member of this transgressing series is the black shale, which, in northern Michigan, is of Lower Devonic (Genesee?) age, but becomes of later and later age southward, at the same time resting always on lower strata. Thus late Upper Devonic (Portage) black shale rests on Lower Hamilton in southern Michigan and northern Ohio; still later beds (Chemung) on the Onondaga (Columbus)

[1] See Clarke, J. M., "Early Devonic History of New York and Eastern North America," *New York State Museum Memoir 9*, 1908.

in central Ohio; while the highest beds rest on Monroan or even Niagaran, in southern Ohio. Continuing southeastward, the black shale rises in the series, until in eastern Tennessee it is of Lower Mississippic age, and rests on Lower Siluric or on Ordovicic strata.[1] (Fig. 11).

DISCUSSION

Professor Calvin

I have studied the Saint Peter sandstone in Iowa, Wisconsin, Minnesota, and Illinois, and nowhere have I seen any marked indications of cross-bedding such as would be consistent with an aeolian origin of the formation. In Iowa and Minnesota there are few structural bedding planes seen in fresh sections, but those that do exist are always horizontal and parallel. Bedding planes are more numerous in this sandstone west of Ottawa, Ill., but they are all precisely of the character one sees everywhere in aqueous sediments. When the Saint Peter is exposed on sloping hillsides, by a process akin to exfoliation, it breaks off in thick flakes parallel to the exposed surface and so often presents a false appearance of cross-bedding; but this feature has no relation to the original structure. One hardly needs to go to the Libyan desert to ascertain the characteristics of aeolian sands. The region around the south end of Lake Michigan affords ample opportunity, nearer home, to study the structural features and topographic forms of wind-blown deposits. I have seen nothing in the Saint Peter suggesting similar origin. Furthermore, the Saint Peter occasionally contains marine fossils, as shown by Winchell and Sardeson.

[1] See Grabau, "Types of Sedimentary Overlap," *Bull. Geol. Soc. Amer.*, Vol. XVII, pp. 593–613.

CORRELATION TABLE I

		Champlain Valley	Black River and Mohawk Valleys	Western New York	Appalachian Southern Penn. Maryland / Tenn.	Interior Cincinnati Region / Upper Mississippi Valley, Ill.
ORDOVICIC	Upper or Trentonian	Utica Trenton	Basal Oswego Lorraine Frankfort / Frankfort Utica Trenton	Queenston Shale Basal "Oswego" s.s. Lorraine Trenton	Juniata / Bays Bald Mt. / Sevier Eden Utica Trenton	Richmond-Maquoketa Maysville / Hiatus and Disconf. Eden ? Point Pleasant / Galena
	Middle or Chazyan	? Black River ? C, B, A Chazy Hiatus and Disconformity	Black River / Bl. Riv. Lowville / Low Pamelia Hiatus and Disconformity / Hiatus and Disconformity	Hiatus and Disconformity	Chambersburg Stones River Group / Chickamauga, etc. Hiatus	Black River Upper Stones River Upper St. Peter Hiatus and Disconformity (often masked)
	Lower or Beekmantownian	E, D, C, B, A Beekmantown	Theresa "Potsdam" / Little Falls Dolomite Hiatus and Unconformity	Lower Beekmantown Hiatus and Unconformity	Disc. Beekmantown Shenandoah / Knox	Lower St. Peter Lower Magnesian
Sub-jacent		Upper Cambric	Pre-Cambric	Pre-Cambric	Upper Cambric	Upper Cambric

A "disconformity," as defined by Grabau, is an erosional unconformity, without discordance of dip.

CORRELATION TABLE II

		Michigan, Ohio, and Canada	West and Central New York	East—Central New York	Helderbergs and Penn.
SILURIC	Upper or Monroan	Hiatus and Disconformity Detroit River Series: Lucas Dolomite, Amherstburg Lime, Anderdon Limestone, Flat Rock Dolomite Hiatus and Disconformity Sylvania Sandstone Hiatus and Disconformity Bass Island Series: Raisin River Series, Put-in-Bay Series, Tymochtee Shale, Greenfield Dolomite Hiatus—Disconformity	Hiatus and Disconformity Akron Dolomite Bertie Waterlime Hiatus and Disconformity	Manlius Limestone Rondout Waterlime Cobleskill Limestone Braymans Shale Binnewater Sandstone Hiatus—Disconformity	Manlius, Rondout, Cobleskill, Rosendale: Lewistown Limest. Hiatus—Disconformity
	Middle or Salinan	Salina—Salt, Gypsum and Lutites	Salina: Camillus, Syracuse, Vernon, Pittsford Hiatus & Disc.	Salina Hiatus, Disconformity	Longwood Shales (High Falls Shales) Green Pond Conglomerate (Shawangunk)
	Lower or Niagaran	Hiatus—Disconformity Niagara, Clinton — Wisconsin: Guelph, Racine, Waukesha, Mayville Hiatus and Disconformity	Guelph Lockport Rochester Clinton . . : Clinton Shales and Limestone, Medina sandstone (sens-strict.)	Niagara Clinton (of type-section) Oneida Conglomerate Hiatus and Disconformity	Hiatus and generally an Unconformity
ORDOVICIC		Richmond	Queenston Shales	Frankfort Shales	Hudson Shales